mains adaptor switch

improves adaptor efficiency

Mains adaptors are used more and more frequently to power small equipment. A drawback of this is that even when the equipment is switched off, the adaptor continues to draw a small current from the mains supply. The present switch reduces this current and at the same time offers the incidental benefit of decreasing the stray field around the adaptor.

INTRODUCTION

The use of a mains adaptor for powering small equipment has an important advantage in that it enables the equipment to be used anywhere in the world. All that is necessary is for the adaptor to be suitable (as far as input voltage and frequency are concerned) for use with the local mains supply. This is inexpensive and efficient. Unfortunately, it also has a drawback: the adaptor works independently of the equipment it powers. This means that even when the load is switched off, the adaptor continues to operate. In other words, it goes on taking energy from the mains supply.

If the adaptor is a modern type based on a switch-mode arrangement, the energy loss is small. However, many adaptors consist merely of a transformer, rectifier, buffer capacitor and, sometimes, a voltage regulator. This kind of setup is not very efficient which means that there is a certain amount of energy loss: in practice around one watt. Another less pleasant property is that the transformer generates a stray field. This field may be so large that in order to comply with the MPRIII norm the distance between the adaptor and its load must be not less than 30 cm (12 in).

Electrical characteristics

Current drain of detector	*<75 µA*
Maximum adaptor rating	*20 W*
Input voltage	*5–18 V*
Power reduction factor	*>50* *(with idling adaptor)*

DETECTORS

At he primary side of the transformer, the mains adaptor draws energy from the mains supply. At the secondary side, it supplies energy to a load. In the

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absence of a load or when the load is switched off, no current flows at the secondary side. However, owing to non-ideal properties, a small amount of energy continues to be taken from the mains supply and this must, of course, be limited.

When there is definitely no load at the secondary side of the mains adaptor, the adaptor may be switched off. This function is provided by the switch described in this article. It could be said that the switch monitors the output voltage of the adaptor. It should be noted that the switch can work correctly only when the adaptor uses an internal buffer capacitor.

The switch provides two functions: it switches the adaptor on and off periodically and it works as a voltage-dip and current detector. In practical operation this means that the adaptor is switched on for 200 ms at intervals of 1.5 minute, during which time the buffer capacitor in the mains adaptor is (re)charged.

The detector which signals a drop in voltage monitors the voltage across the buffer capacitor in the mains adaptor. When this potential is about to drop below a certain predetermined value, the adaptor is switched on immediately.

The voltage detector has another important function, which enables the output voltage of the adaptor to be held steady. In many mains adaptors the output voltage rises sharply when the output terminals are ope-circuited. In the present adaptor the mains voltage is switched off after about 200 ms as soon as the output voltage rises above the preset value. This function is independent of the current detector.

The current detector determines whether or not the load is switched on. When a current flows through the load, the adaptor is actuated, and the load is switched on. How the theory becomes a practical arrangement is shown in **Figure 1**.

CIRCUIT DESCRIPTION

The lower part at the left of the circuit diagram in **Figure 1** comprises the primary side of the mains adaptor, and the upper section, the secondary side. Although not immediately evident from the diagram, the circuit uses only standard components. At the same time, it has been kept compact and is readily constructed on the printed-circuit diagram in **Figure 2**. Its electrical characteristics are conform relevant specifications.

In the design of the circuit, great care was given to minimizing the energy consumption. Network R_1-R_2-C_1, diodes D_1–D_3 and buffer capacitor C_2 ensure a fairly steady 5 V supply voltage. The current drawn from the mains supply is about 3.4 mA. The energy dissipated in the circuit is small: only 12.8 mW.

The mains adaptor is switched on and off by triac Tri_1. Since an inductive load is switched, constant drive is needed. Assuming a gate current of 5 mA, the triac may be triggered in each quadrant. To reduce the energy consumption, it was decided to use a pulsating trigger current. The duty factor is 10 per cent and the trigger duration is not smaller than 20 µs (which is the lower threshold of the triac). Keeping the trigger frequency high ensures minimal asymmetry between the two periods and insignificant direct current. This arrangement results in an average trigger current of only 0.5 mA.

The trigger pulses are generated by IC_{1b}, whose gate current is limited by R_{10}. With component values as specified, the trigger pulses are 27 µs long (time constant R_8-C_7), and are repeated every 230 µs (time constant $0.7R_9$-C_7). These values result in 78 trigger pulses per 20 ms period, which is high enough to cause the earlier mentioned undesired side effects (direct current) to be suppressed. The trigger circuit is switched via the reset input (pin 10).

The trigger circuit is controlled by a second astable multivibrator (AMV), IC_{1a}. This stage produces a 200 ms pulse every 90 seconds. During the 200 ms that the output is low, the reset input of IC_{1b} is high after the level has been inverted in T_1, whereupon the

Figure 1. Circuit diagram of the mains adaptor switch. The design is based on standard components: special components and esoteric circuitry are not used.

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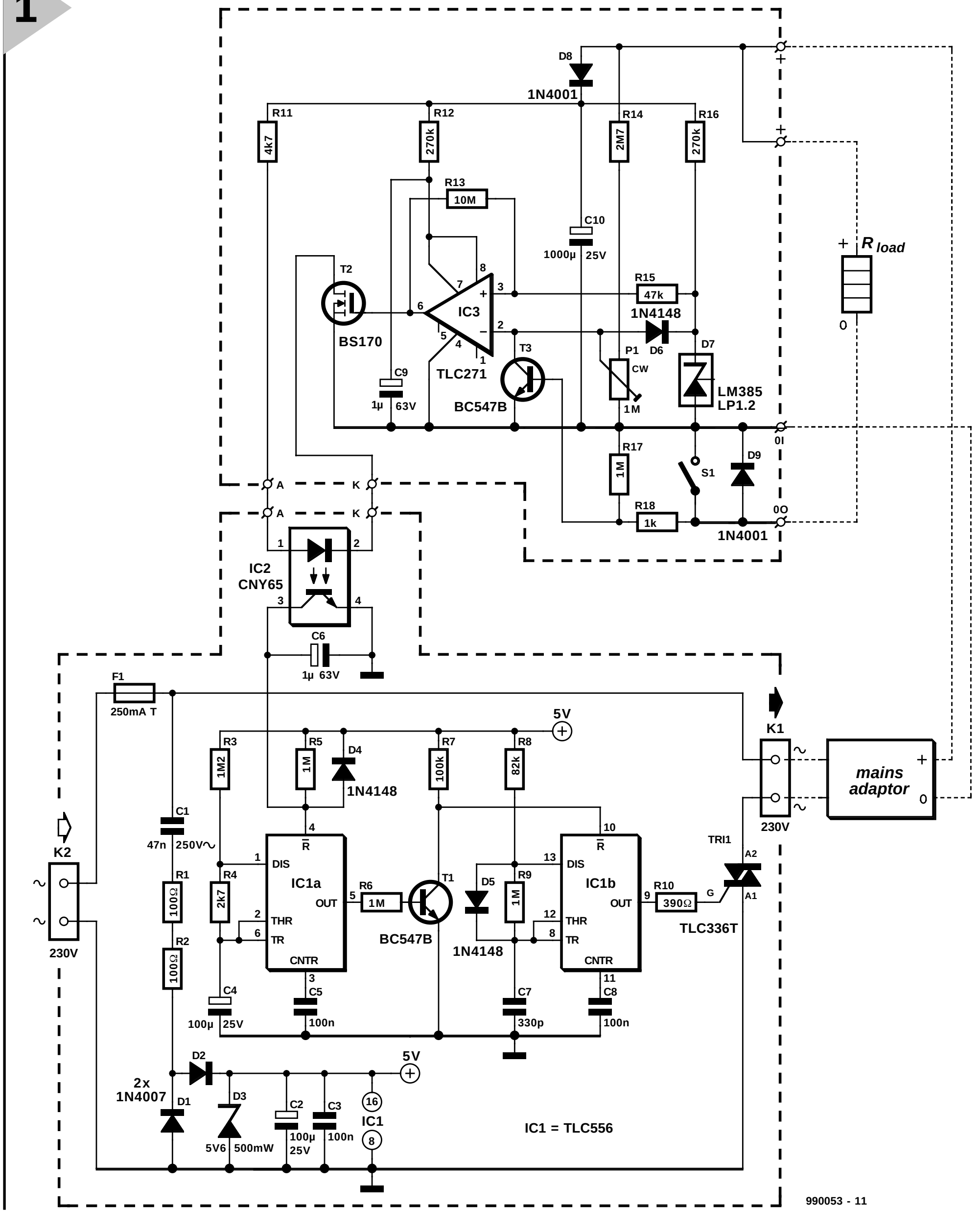

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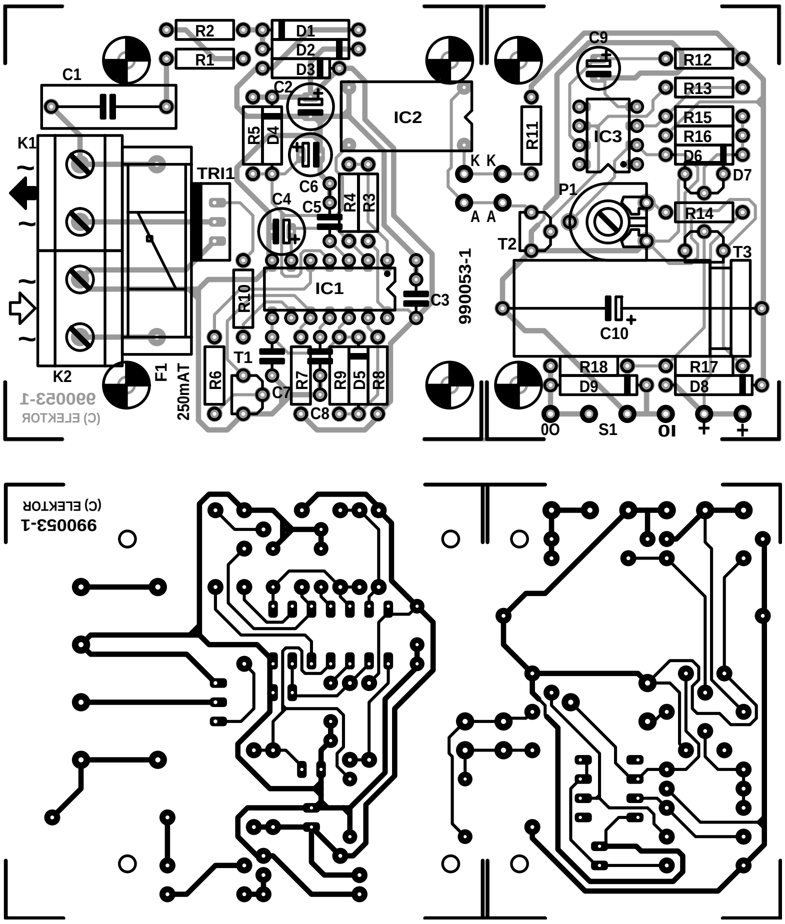

Figure 2. The printed-circuit board for the adaptor switch should normally be cut into two sections as indicated.

triac is triggered.

To ensure that there is sufficient time for the reservoir capacitor in the adaptor to be charged after the system has been switched on, a special start-up circuit, R_5-C_6-D_4, has been added. The charging of the capacitor is essential to provide the secondary side of the adaptor with a supply voltage.

The reset input of IC_{1a} is also used to trigger the triac in case early recharging of the buffer capacitor becomes necessary. The need for early recharging is signalled by the secondary detector circuit. Since the circuit is powered directly by the mains supply, the secondary detector circuit is linked to IC_{1a} via an optoisolator to ensure the requisite electrical isolation between the two.

Note that the triac is deliberately not provided with a snubber network, since it is disabled without any problem as soon as the buffer capacitor is charged to a sufficient degree.

ADDITIONAL DETAILS

The detector circuit was designed to carry out its work with as little energy dissipation as feasible. The basic design requirement was that the circuit could be operated for not less than 2 minutes by a 1000 µF capacitor. A further requirement was that the detector could be set to work with voltages between 5 V and 15 V.

The reference voltage is produced by zener diode D_7, which can operate with a current of only 10 µA.

The series resistor in the supply line for the op amp results in the top end of the voltage range over which the device is to be operated to be raised from 18 V to 20 V.

An interesting aspect of the present design is that the optoisolator is switched via a separate MOSFET, T_2.

When the adaptor voltage drops below the threshold level set with P_1, the output of the op amp goes high, whereupon the triac is triggered. Resistors R_{13} and R_{15} provide the requisite hysteresis.

Detector diode D_9 may be switched into circuit, or out of it, by switch S_1. With component values as specified, a current of only 0.5 mA is sufficient to switch on T_3. The periodical switching is actuated continuously, which ensures that the mains adaptor remains linked to the mains supply.

A final remark about the stray field produced by the mains adaptor. When the adaptor works without load, it is switched on for only 1/450 of the time. The consequent reduction in the *H*-field is directly proportional with this factor.

CONSTRUCTION

The small dimensions of the mains adaptor switch make it ideally suitable for being enclosed in a plastic (ABS) case with integral mains supply lead

Parts list

Resistors:
R_1, R_2 = 100 Ω
R_3 = 1.2 MΩ
R_4 = 2.7 kΩ
R_5, R_6, R_9, R_{17} = 1 MΩ
R_7 = 100 kΩ
R_8 = 82 kΩ
R_{10} = 390 Ω
R_{11} = 4.7 kΩ
R_{12}, R_{16} = 270 kΩ
R_{13} = 10 MΩ
R_{14} = 2.7 MΩ
R_{15} = 47 kΩ
R_{18} = 1 kΩ
P_1 = 1 MΩ preset

Capacitors:
C_1 = 0.047 µF, 250 V~
C_2, C_4 = 100 µF, 25 V, radial
C_3 = 0.1 µF, ceramic
C_5, C_6 = 0.1 µF, MKT (metallized polyester)
C_6, C_9 = 1 µF, 63 V, radial
C_7 = 330 pF, ceramic
C_{10} = 1000 µF, 25 V

Semiconductors:
D_1, D_2 = 1N4007
D_3 = zener diode, 5.6 V, 500 mW
D_4–D_6 = 1N4148
D_7 = LM385LP1.2
D_8, D_9 = 1N4001
T_1, T_3 = BC547B
T_2 = BS170

Integrated circuits:
IC_1 = TLC558
IC_2 = CNY85
IC_3 = TLC271CP
Tri_1 = TLC3361 (STS)

Miscellaneous:
K_1, K_2 = 3-way terminal strip for board mounting, pitch 7.5 mm
S_1 = toggle switch, single make contact
P_1 = Fuse holder with protective cap and 250 mAT fuse for board mounting
Mains adaptor case: Bopla (available from Phoenix at 01296 398355)
PCB Order no. 990053-1 (see Readers Services towards the end of this issue)

specially designed for applications like the present. The photograph in **Figure 2** shows that the switch is simply connected between a mains supply outlet and the mains adaptor.

The printed-circuit board (which is available ready made – see Parts List) may be cut into two, which is, in fact, essential when the switch is to be fitted in the special enclosure. The two sections are mounted one above the other with the aid of 10 mm plastic spacers. They are interlinked by short lengths of insulated circuit wire between terminals 'K' and terminals 'A'.

Input terminals O_I and +, output terminals O_O and +, and switch S_1, are best located on the front panel of the enclosure.

There is little that can be said about populating the board sections other than that it is advisable to use the specified components and that the fuse holder should preferably be one with a protective cap. It is also advisable, but not essential, to use shrink sleeving on the input and output terminals and the the switch terminals.

Before finalizing the construction, drill a 4 mm hole in the lid of the case exactly opposite P_1. This enables the switching level of the voltage detector to be adjusted with P_1 after assembly has been completed.

Insert the plug on the mains adaptor into the socket inlet on the switch; connect the output of the adaptor to the input terminals of the switch, and the equipment to be powered to the output terminals of the switch. Finally, insert the adaptor switch into a suitable mains outlet socket.

[990053]